SCIENTIFIC MANPOWER RESOURCES OF THE USSR

Address presented by Herbert Scoville, Jr. at the National Electronics Conference, Chicago, Illinois, on 3 October 1956.

Scientific Manpower Resources of the USSR

As you all know, the scientific-technical manpower shortage is a matter of real concern in this country. I am sure that at this National Electronics Conference, one would find that there are many more people recruiting scientists than there are people looking for jobs. The electronics industry is probably one of the most critical from the point of view of shortage of technical manpower. Since there are not enough electrical engineers to go around, United States industries are directing their competitive skill toward luring engineers and scientists to their companies.

This competition for scientific manpower is not limited to industries within the United States, but also exists between nations such as the United States and the Soviet Union. In this technological age, that nation with the greatest supply of high quality scientific manpower will be the one to lead the world. It is for that reason I believe it is useful to spend some time studying the scientific manpower resources in the USSR.

The analysis of manpower resources can be divided into two main parts. First, there is the quantitative aspect, i.e., the number of trained people in various fields and the rate at which this manpower pool is being increased. However, second and probably most important, is the quality of the scientific manpower which is available to the Soviet Union. It is the qualitative aspects which are of course most difficult to evaluate, but I shall attempt to analyze this part of the problem as best one can, first, by looking at the educational system and, second, at the quality of the output of the Soviet scientists.

Today, the United States and the Soviet Union each has a scientific technical manpower force of about 1.2 million. In research and teaching, the Soviet Union has a force only about 2/3ds that of the United States (175,000 vs 265,000). In research alone, they have only about half the number we have (120,000 vs about 210,000). On the average each year, though we turn out 10% more college graduates than they, they graduate many more in science and engineering than we do. For example, in 1955, 60% of Soviet full-time students graduated in scientific-technical fields as compared to only about 25% in the United States. In engineering alone, the Soviet Union graduated twice as many as did the United States.

Chart 1, Graduates per Year in All Scientific Fields, shows the steady increase in both countries in numbers of graduates in all science fields from 1930 to 1960. In 1930, both countries were almost equal, each graduating about 36,000 science students. The 1933 drop to 19,000 in the Soviet curve resulted from a lengthening of courses. The rise in 1935 (in the Soviet curve) reflects the expanded enrollments in 1930/32. Both

the United States and Soviet curves show wartime losses from about 1942/43 to 1945. Soviet losses were greater than ours. They dropped to about 22,000 in 1945 compared to about 39,000 in the United States. Rapid post-war increases are shown for both countries. We climbed faster and farther and reached a peak of about 134,000 science graduates in 1950, largely under the "GI Bill", and then started declining. They climbed less spectacularly, but note that the Soviet curve did not go into a decline. That curve is still rising. In June 1954, Soviet science graduates outnumbered ours by about 36,000. It is estimated that in 1960 the Soviet Union will graduate about 155,000 science students compared to about 126,000 in the United States.

Chart 2, Graduates per Year in Physical Sciences and Engineering, shows a comparison of Americal and Soviet graduates in the physical sciences and engineering only for the period 1930 to 1960. It will be seen that the general shape of these curves is similar to that for graduates in all scientific fields. Again, one sees that if the estimated trends continue, the Soviet manpower pool in the important physical and engineering sciences fields will soon surpass that in this country. There is nothing that we can do about the slope of the Soviet curve. Our efforts must be placed at changing the slope of the curves for the United States and thereby change the relative position of the two curves. Every effort must be made to build up a larger pool of trained scientists in this country.

Since the Soviet educational system is not only a key factor in the numbers that are produced, but also will determine the quality of the people available for Soviet research and industry, it is important to devote some attention to studying its major features. First, I believe it is very important to look at school-level education in the Soviet Union and here one is immediately struck by the fact that even the elementary schools put a major stress on science. Every student has to have taken five years of physics, five years of biology, four years of chemistry and 10 years of mathematics by the time he finishes high school. The important factor here is not the number of years on each one of these subjects, but that every single student is exposed to a broad scientific background which will permit him, if qualified, to proceed to more advanced scientific studies. By comparison, less than 10% of American high school graduates have taken as much as a year of physics and chemistry and even fewer any advanced mathematics. As a consequence, only a small number of those who might be qualified and eventually might become interested are ever capable of carrying on in scientific fields. Since, in general, scientific courses are more difficult than those in home economics and the like, and since there is tremendous outside pressure for students to get high marks, there is a very bad tendency to discourage students from getting the broad scientific background that is required in order to develop a career in science or engineering.

After completing high school, the better Soviet students enter higher educational institutions. Honor students are admitted without taking entrance examinations, but all others must pass stiff, competitive exams in Russian language and literature, mathematics, physics, chemistry and one foreign language. Most examinations are oral and it may be of some interest to describe their nature. Several days in advance of the date of the test, a student is given a compilation of more than 50 sets of questions, any one of which he may get on his exam. Then on the day of the test, he selects by chance one set of questions on which he must report. He is given about 20 minutes to collect his thoughts and then must stand up in front of the Board of Examiners and give an oral presentation of the answers. This type of exam would, I am sure, be extremely difficult for students of high school age in this country. It teaches students to think on their feet and be able to present their ideas in an understandable form. Providing the questions to the students several days in advance of the test does have, in my opinion, the drawback of putting a premium on the ability to cram for an exam. A student with a good memory might, by very vigorously studying in the few days prior to these tests, get passable marks and yet not have a true appreciation of the subject.

Future Soviet engineers and scientists are trained at one of three types of higher educational institutions:

(1) Engineering and technical colleges offer 4-5 year courses in specialized fields such as machine building, construction, and agricultural mechanization. These colleges prepare engineers and specialists for particular industries. Eight of these colleges are devoted entirely to training in electronics and radio technology. Many others have extensive courses in these fields.

(2) Polytechnic institutes offer 4-6 year courses in broader engineering fields such as civil, electrical, and metallurgical engineering. Students graduate as production engineers and enter the economy. Out of the 25 such institutes in the Soviet Union, 20 have energetics or electrotechnical faculties and 13 have faculties of radio technology or electrophysics.

(3) Universities offer 5-5½ year courses in fundamental sciences. Graduates enter research or teaching--the better graduates are directed to research. All 34 universities in the Soviet Union provide good basic training in physics, mathematics, and electronics.

Almost half a million students enter these Soviet colleges each year. They spend, as indicated, 4-6 years in a rigorous course of study.

Discipline is strict. Attendance at lecture and laboratory sessions is compulsory. As many as 10 comprehensive examinations are given each year. Those who fail are weeded out. Those who do well are rewarded by increased stipends.

While in college, students spend as much as 90% of their time on technical subjects. At the Bauman Higher Technical School in Moscow, probably the best of the engineering institutes in the Soviet Union, about 4300 out of a total of 4800 hours, i.e., about 89% are spent on scientific subjects. At Massachusetts Institute of Technology by comparison, only 2300 out of a total of 2900 hours, i.e., about 78%, are spent on science.

Quality of scientific and technical training in the Soviet Union is generally comparable with that in the United States. As competition for entrance to universities and colleges is very keen, standards are kept high. University faculties are organized so that each department is quite small and teaching often can be done through informal contact between students and staff. Recent visitors to the Soviet Union who have attended lectures or seminars have been very much impressed by the degree of student participation. Students were very prone to enter into discussions and ask questions of the lecturer.

Some United States educators have indicated that the specialization in science which I referred to earlier may be a possible weakness in the Soviet educational system. There is also a tendency in the engineering and technical colleges to concentrate in narrow fields and this specialization may well create a narrowness of outlook and make it difficult for people to adapt themselves to new problems. The textbooks tend to be encyclopedic in nature and lead the student toward learning facts.

As the scientific profession in the Soviet Union is a highly honored and well paid one, the majority of Soviet students wish to prepare themselves for a scientific career. What institute a student attends and what course of study he pursues is largely a matter of State selection. Instead of depending upon individual preference or public appeal to influence the high school graduate's choice of a "major", the Soviets use several effective methods to funnel students into disciplines in accordance with the needs of the State.

(1) They use, of course, propaganda appeals, much as we do, stressing monetary and prestige factors, and in addition point out that it is the Soviet student's duty to prepare himself for usefulness in achieving socialist supremacy.

(2) Another very potent method of channeling students into desired fields is the threat of military draft. Students who enroll at particular specialized schools or in certain courses are given total draft exemptions or continuing deferments. For example, during the war a law was passed listing some 85 technical colleges whose students would be totally exempt from military draft as long as they successfully continued their studies in engineering and technical fields--fields in which there were definite needs. The law still remains in force today.

(3) Also, each college and university has a quota system. There are always more applicants than vacancies in scientific and technical fields. When shortages of specialists are anticipated, quotas are raised thereby admitting larger numbers of people.

(4) Scholarships and stipends serve to channel students into desired study areas. Scientific or engineering students receive more rubles per month than do their fellows who study, say, history. As State needs change, of course, so also does the amount of stipend in a given subject field.

(5) Finally, the larger number of people who have a basic technical training at least at the high school level permits a high degree of selectivity in the use of the scientific manpower resources. The inferior students can be weeded out or placed in positions requiring less ability. Too often in this country, it has been necessary to place people in positions for which they were not adequately qualified, because the supply of trained people which are being fed into the scientific manpower hopper is too small to satisfy even the major demands.

A quarter of a million students each year successfully complete their studies and graduate from college in the Soviet Union. Here again, the State steps in--graduates are assigned to jobs in the economy. Though some graduates may occasionally use outside influence or political "pull" to get desired assignments, most students consider it just that they work wherever the State assigns them. After all, they reason, the State paid for their education and training and, therefore, they are obligated to repay the State by their work. The

best students usually want to go into research and do so. Once assigned, a graduate has little opportunity for transfer. The engineer or scientist must remain in his assigned place for at least three years. Hence, it is that 80% of Soviet science graduates are actually employed in scientific fields while only 60% of our science graduates work in their fields.

Graduates and researchers who show exceptional promise are selected for advanced training. After studying for three years and preparing a dissertation, they are awarded a "Candidate" degree, roughly comparable to our Ph.D. The Soviets already have more science "Candidates" than we have Ph.D.'s in science. Chart 3, Higher Degrees in Science Awarded Annually, shows the numbers of Soviet "Candidate" and United States Ph.D. degrees awarded in science each year from 1935 to mid-1954. As early as 1935, they awarded 18,000 "Candidate" degrees while we granted only about 15,000 Ph.D. degrees that year. As you can see, they have continuously awarded more higher degrees than we have, except during the war years. In June of 1954, they granted 8,100 "Candidate" degrees compared to only 5,000 Ph.D.'s granted in this country. All in all, by mid-1955 there was a total of 55,000 Ph.D.'s in science in this country. 70,000 Soviets held "Candidate" degrees in science.

The ultimate test of the quality of the Soviet scientific manpower is, of course, the results of the research and development which is being carried out in the Soviet Union. In areas relating directly to the build-up of national power and military strength, the Soviets have made remarkable progress and excel in some specialized fields. In areas relating to consumer goods and comforts, the progress has been slower and at best well behind the West. In the field of nuclear research, they have achieved significant advances which might best be demonstrated by their work in developing particle accelerators. The Soviets will have very shortly in operation a 10 BEV proton synchrotron which will be the largest in the world. This accelerator was visited by a number of foreign scientists this summer and all were much impressed by the quality of the work involved. The supplementary instrumentation was also of high quality. United States and Western European laboratories are designing and constructing accelerators in the 30 BEV range, due for completion in 1960-61, but the Soviets are already planning a still larger accelerator up to 50 BEV. Despite the high quality of these devices, I believe it was the feeling of United States scientists that the research programs using this equipment were more limited than would have been the case in the West.

In the field of atomic weapons, the Soviet progress has also been rapid. Evidence of this is demonstrated by the fact that within the past month, it has been announced that the Soviets have conducted four nuclear tests. The Soviets also have an extensive nuclear reactor

program, but the reactors which have been shown to the West have not demonstrated any outstanding new developments. They do, however, have an extensive program for developing nuclear power since their Sixth Five-Year Plan calls for the completion by 1961 of plants with a capacity of 2 to 2½ million kilowatts. If successful in achieving this goal, this would be a major advance, but it must be remembered that such a program might also produce substantial quantities of fissionable materials for military purposes.

They have also demonstrated ability in the field of aeronautics. The development of the TU 104, a Jet Transport plane, places the Soviet Union in a strong competitive position in the design of modern long range transports. Three of these aircraft were recently used to bring the Russian Ballet to London and they will shortly be placed into regular use between Prague, Moscow and points East.

The Soviets have recently announced the existence of a number of high-speed electronic digital computers. The largest of these, the BESM, is comparable to some of the better high speed computers in the United States and United Kingdom, although not quite as good as a recently developed United States computer. Nesmeyanov, President of the USSR Academy of Sciences, has announced that high speed computer research is one of a number of areas of fundamental importance in which the Soviets will concentrate their efforts. As he stated, research in this field is likely to lead to a scientific breakthrough.

And this brings us to the field which is of some interest to you people, electronics. In virtually all branches of electronics, with the possible exception of high-power radio technique, the Soviets were far behind the West at the end of World War II. Perhaps in no other field of science and technology, with exception of the nuclear energy field and guided missiles, has the Soviet progress of the last 10 years been so intense and productive. Today, the USSR is a major factor in electronics and a potent challenger of the electronics leadership of the United States. The Soviets are the world leaders in the relatively new branch of electronics of radio astronomy. They have maintained high competence in communication theory. They have reached high native competence in the field of electronics equipment and instrumentation directly relevant to their military requirements. In the field of "consumers" or civil electronics (such as television, civil telephone and telegraph), they are well behind the West, even by their own standard. They propose, however, to improve this field under their Sixth Five-Year Plan. Recent visitors to Russia were impressed by the increased number of TV sets available this year in the stores.

A few examples of their current program in electronics and telecommunications, as reflected in their own unclassified releases in the Soviet newspapers, radio, technical publications, and papers and discussions at the recent international conferences:

(1) Early in 1955 (MORSKOY FLOT, #3, March 1955), the Soviets published technical characteristics of STVOR - a modern precision 3 cm radar of native design used for "close quarters" navigation in small ships. This radar has 0.1 microsecond pulse, 80 kw peak power, and a range of 100 feet to some 25 miles. It is a miniaturized version (about 500 lbs.) of an older 3 cm navigational radar, NEPTUN (about 1600 lbs., 30-50 kw peak power), used in larger marine vessels for several years. The radar is coupled to the ship's gyroscope and is provided with the facilities for the reception of radio beacons. Under the latest Five-Year Plan, the Soviets propose to equip all maritime, technical and port fleets and the service auxiliary ships with radars, including a new radar of higher range and smaller minimum range for larger ships, and to provide television receivers on their ships for all-weather electronic pilot service from ground radars located at the most important ports and sections of maritime routes.

(2) A new and original Soviet development in travelling wave tubes, SPIROTRON, was announced by the Soviets at the International Conference on High-Frequency Tubes in Paris, May-June 1956. (TCHERNOV Tube.) I understand that the basic novel idea of the tube is a new type of electronic gun injection system, and that the work indicates a very creditable level of competence in travelling-wave tubes.

(3) At the same conference, Professor Naumenko presented a paper on wide tuning-range, millimeter-wave klystron oscillator, operating in 7 to 19 mm bandwidth, having a power of some 5-10 milliwatts. During the discussion of these klystron, Professor Naumenko referred to Soviet work on a very high-power klystron operating at LC frequencies. I understand that this work of the Soviets is on a par with the West.

(4) The Soviets are doing a creditable job in the field of modern telecommunications. At the Scientific Congress for Nuclear Energy and Electronics in Rome earlier this year, Professor Vladimir SIFOROV presented a good theoretical paper on forward-scatter and mentioned tests on a "beyond-horizon, forward-scatter, multichannel Soviet system comprising many relay sectors." Two native Soviet microwave radio-relay systems are being placed in operation between Moscow and Ryazan: STRELA M providing 24 telephone channels and designed for

multichannel service in a system up to 2500 km long, and STRELA T for transmitting several television channels. A true wide-frequency multichannel radio-relay system has been produced in a prototype form, capable of handling up to 12 television channels or up to 3,000 telephone channels. The system is to operate at wavelengths not to exceed 7 to 9 cm and in lengths up to several thousands of kilometers (Moscow, TASS, July 1956). The Soviet Sixth Five-Year Plan calls for some 10,000 km of new radio-relay lines and an increase of their 1950 radio-relay facilities some 60 times. A new Soviet high speed facsimile equipment has been announced recently (Promyshlenno-Ekonomicheskaya Gazeta, July 1956) and a fully electronic high-speed teleprinter is reported under development, the first model to use vacuum tubes and the later miniaturized version to use transistors. (Evening Moscow, May 1956)

In summary, (1) the Soviets are not at present ahead of the United States in total scientific and technical manpower, but they are advancing rapidly and, if present trends continue, will surpass the United States; (2) the Soviet educational system is designed at all levels to turn out scientists and engineers; and, (3) the quality of Soviet developments is good in almost all its fields which have been emphasized, and electronics is certainly one of those in which they have demonstrated a high position of native competence.

CHART 1

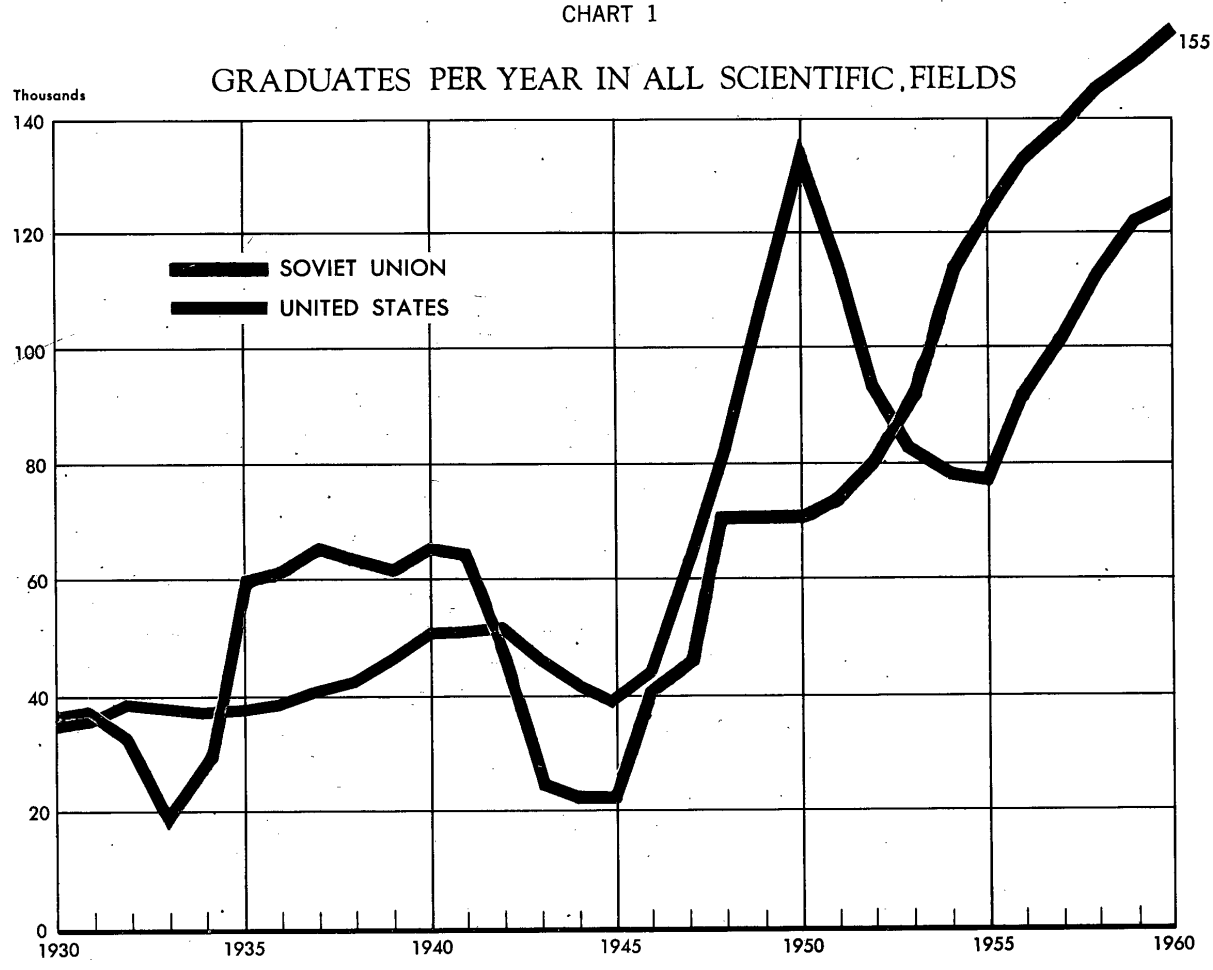

CHART 2

GRADUATES PER YEAR IN PHYSICAL SCIENCES AND ENGINEERING

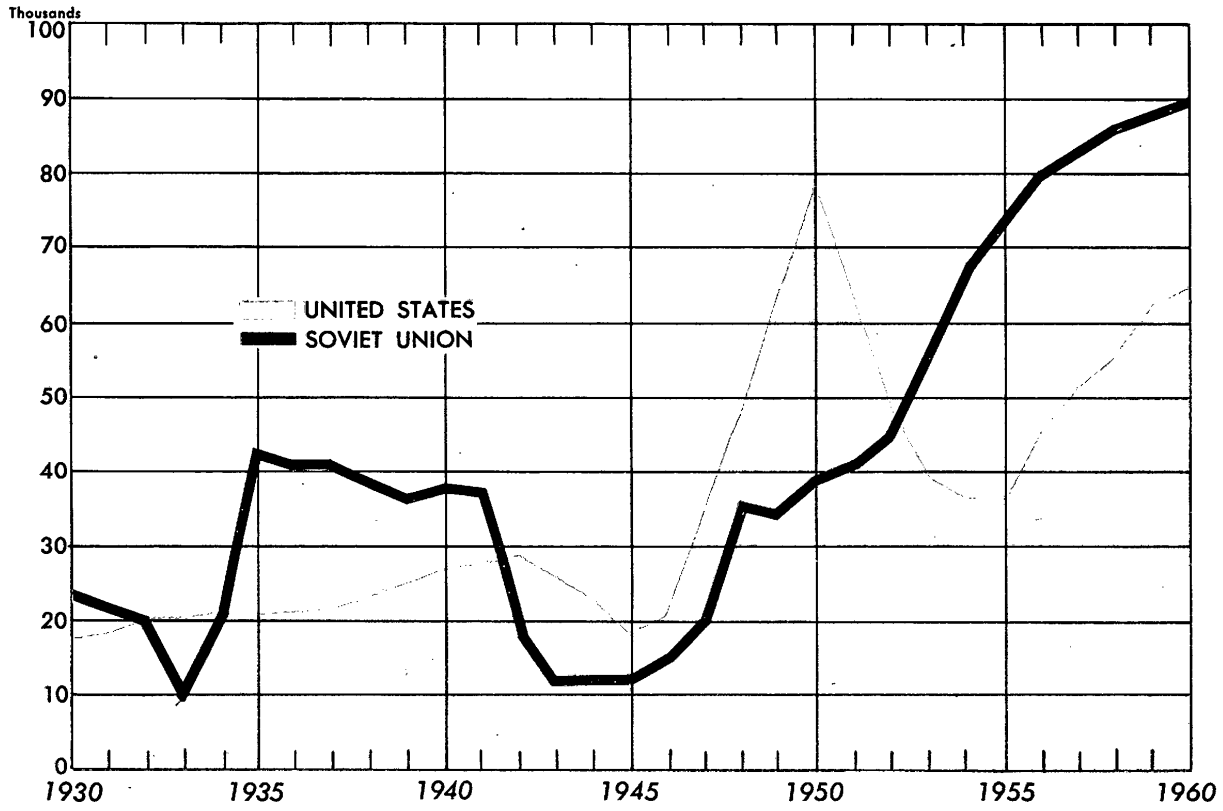

CHART 3

HIGHER DEGREES IN SCIENCE AWARDED ANNUALLY